II. Description of DSN Systems

INTRODUCTION

A. System Simulation Models, *D. C. Card*

1. Introduction

The functional design and validation of design concepts for complex systems of the magnitude of the Deep Space Network (DSN) require the aid of powerful system modeling techniques, as well as practical methods for employing models as engineering tools. Monte Carlo simulation of systems operations has provided an effective means of analyzing the influence of system structure upon the dynamic flow of traffic through the systems in many types of application. Monte Carlo simulation methods provide one effective aid to system analysis in the DSN for two basic reasons:

(1) The DSN is a complex of identifiable elements through which traffic elements of several distinct types flow.

(2) The General Purpose Simulation System (GPSS) program is readily available and provides a fairly complete and adaptable language for the construction and operation of simulation models on high-speed digital computers.

2. The GPSS Program

A useful model for system analysis must have a structure that is representative of the structural elements of the system being studied; therefore, before a simulation model is constructed, a functional flow diagram and logical flow and control diagram for the system must be available. Once these requirements are met, the interpretation of system diagrams into GPSS language blocks is reasonably direct. Of primary importance to the codes is complete understanding of the logical operation of GPSS block types and overall simulation control.

The IBM GPSS program is currently available in two versions on the JPL IBM 7094 and 360/75 systems; GPSS III is located on the 7094 system and GPSS/360 is on the 360/75 system. The GPSS/360 version is somewhat more versatile than GPSS III; greater capacity has been provided for simulating systems of greater complexity in more detail.

The GPSS is a Monte Carlo simulation system that provides a high-level structural language for interpreting

functional and logical diagram blocks into simulation model blocks. The program is most directly applicable to the simulation of systems in which the study of flow characteristics of discrete traffic units through the system is of interest. Simulation system time is discrete, and the unit of time is completely arbitrary.

The GPSS program deck provides the random number generators and the overall flow control logic for the execution of simulation models, as well as computational and output format logic for simulation model statistical output. The input deck contains the model structure and the characteristic parameters to represent the flow through the system; it also contains cards to control the accumulation and tabulation of statistics.

After the model structure has been fully determined and compiled, the program begins simulation "runs" by generating traffic units (called *transactions)* according to rules specified by the programmer. These transactions are the dynamic input to the system model. The number of transactions, first generation time, arrival rate distribution, and priority levels are controlled by the programmer's input specification.

The flow of transactions through a model is controlled by system blocks. The path of transactions through the model follows the block sequence, and may be controlled logical transfers, duplication of blocks, and termination blocks, as well.

Transactions may carry with them several distinct parametric values, which may be introduced or altered at any stage of the system. These parameters provide a powerful, direct method for identifying and controlling distinct traffic elements depending upon individual characteristics. Parameter values may be used to indicate traffic type for flow logic control, characteristic service time for one or more service elements in the system, etc.

The output from GPSS simulation runs is orientated toward the study of traffic flow characteristics. The GPSS language provides blocks which "monitor" flow of traffic at any desired point in the system model. Flow statistics of several types, such as overall transit time, transit time between specified points, arrival rate, etc., may be accumulated and tabulated for convenient output. Further, statistics are accumulated for queue contents, waiting times, and for facility utilization factors.

The following IBM publications should be referred to for detailed description and operating instructions for the GPSS:

(1) GH20-0304-4, General Purpose Simulation System/360: Introductory User's Manual.

(2) H20-0326-2, General Purpose Simulation System/360: User's Manual.

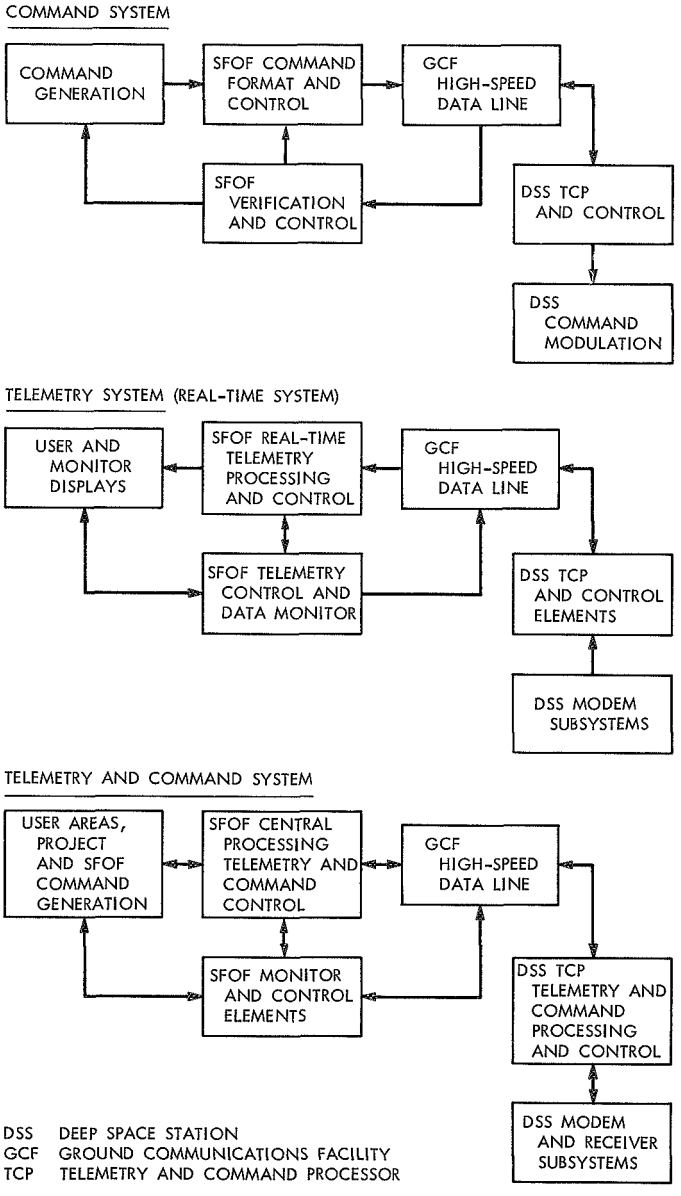
COMMAND SYSTEM
COMMAND GENERATION
SFOF COMMAND FORMAT AND CONTROL
GCF HIGH-SPEED DATA LINE
SFOF VERIFICATION AND CONTROL
DSS TCP AND CONTROL
DSS COMMAND MODULATION
TELEMETRY SYSTEM (REAL-TIME SYSTEM)
USER AND MONITOR DISPLAYS
SFOF REAL-TIME TELEMETRY PROCESSING AND CONTROL
GCF HIGH-SPEED DATA LINE
SFOF TELEMETRY CONTROL AND DATA MONITOR
DSS TCP AND CONTROL ELEMENTS
DSS MODEM SUBSYSTEMS
TELEMETRY AND COMMAND SYSTEM
USER AREAS, PROJECT AND SFOF COMMAND GENERATION
SFOF CENTRAL PROCESSING TELEMETRY AND COMMAND CONTROL
GCF HIGH-SPEED DATA LINE
SFOF MONITOR AND CONTROL ELEMENTS
DSS TCP TELEMETRY AND COMMAND PROCESSING AND CONTROL
DSS MODEM AND RECEIVER SUBSYSTEMS
DSS DEEP SPACE STATION
GCF GROUND COMMUNICATIONS FACILITY
TCP TELEMETRY AND COMMAND PROCESSOR

Fig. 1. Functional flow diagrams for separate and combined telemetry and command systems

3. Simulation Models for the DSN

Since the DSN is a large complex network system, it was decided that the most feasible approach to the construction of system models would be to provide separate models for each of the DSN systems, then combine the models into an overall DSN model. This method allows the functional aspects of the model system to be tested and validated in detail. The capability of GPSS models for modularity permits the separate system models to be "patched together" at the interfaces in correspondence with DSN design, and with relatively little alteration of system blocks. At this time, representative models for the Telemetry and Command Systems (Multiple-Mission Command and Multiple-Mission Telemetry Systems) are being constructed and exercised. The results should provide a good test of the modular aspects of the GPSS.

As a simple example of separate system model construction and the ultimate combination of models, consider a single branch of the Command System and the Telemetry System, as shown at a gross detail level in Fig. 1. The system elements and flow logic are assembled separately for each system, and the simulation model is constructed and executed in order to "debug" and validate the model logic. Then, the models may be combined as represented by the bottom diagram, with corresponding logical control for the various traffic elements and data handling operations in the system.

4. DSN Multiple-Mission Command System

At this writing, a fairly complete simulation model of the DSN Command System has been constructed and executed, using GPSS/360. The simulation model was constructed to be representative of the functional elements diagram and logical flow and control diagram.[1] The characteristic values for parameter, as well as some slight modification and elucidation of the original flow elements, were derived from design review meetings and direct communication with the system engineer. The results of the simulation runs provided no essential surprises, since the command system by itself puts no appreciable burden on the data processing and data handling elements of the DSN. However, it is expected that the results will be more fruitful when various systems designs are combined into unified simulation models. Work is currently proceeding on the Multiple-Mission Telemetry System model effort. The two system models will be expanded and combined in order to evaluate the design concepts and possible variation of these concepts.

[1]Contained in *Deep Space Network/System Requirements: DSN Command System* (Rev. A), December 1969 (JPL internal document).

B. Monitor System, *J. E. Allen*

1. Introduction

Historically, the Monitor System has been characterized as a data-gathering system and as such has been relegated the role of DSN system performance monitoring. The Monitor System provides the capability to determine failures to the facility subsystem level and distribute data to the DSN Tracking, Telemetry, Command, and Operations Control Systems.

The DSN Monitor System provides the capability for sensing certain characteristics of the various elements of the DSN, for processing and displaying these data for the use by DSN operations personnel, and for storing these data for later analysis. Monitor data are used for determining DSN status and configurations, for guidance in directing DSN operations, for providing alarms of nonstandard conditions, and for analysis of the quality and quantity of data provided to the projects.

DSN monitor data are defined as a selected subset of the machine-accessible facility monitor data (DSIF, GCF, and SFOF) that monitor the state, performance level, and configuration for any operationally active element of the DSN.

The scope of the Monitor System is defined as the specification, acquisition, conversion, transmission, selection, reduction, error detection, distribution, storage, and display of DSN facility and DSN system monitor data.

This article will be confined to the DSN Monitor System as the SFOF through 1971 and, in a brief sense, defines the facility interface with the Monitor System.

2. Application

The Monitor operation at the SFOF is primarily an automatic operation with personnel manning the input/output device and analysts evaluating the data. The software for the Monitor resides in the IBM 360/75 computer and is linked through the CDC 3100 computer, which in turn acts as the buffer for digital TV displays.

Raw data from the DSN sites via high-speed data lines (HSDLs) are input to the 360/75 computer and are collected in the DSN data accumulation bank. They are processed, evaluated, formatted, filed, displayed, and distributed in real time to DSN monitor data users. The stored data are validated in terms of quality and quantity within 12 h after each pass. At that time, mission data and questionable data are recalled from the individual sites and merged in the stored data file in a time-ordered fashion. Following the data recall and data merge, a Monitor System Data Record (SDR) is written on magnetic tape for storage.

3. Operational Description

The operation and control of the DSN Monitor System may be characterized as a number of open loops between the SFOF Central Processing System (CPS) and the DSIF Monitor System at the deep space station (DSS). Many of the monitor functions now performed manually or semi-automatically at the SFOF will be done automatically in the Mark III A era.

4. Basic Characteristics

The basic characteristics of the DSN Monitor System are as follows:

(1) Uniform instrumentation and reporting on status of elements of the DSN systems.

(2) Automatic and semi-automatic detection and reporting of all specified characteristics required of the DSN to operations and systems control points.

(3) Unified control and distribution of facility and DSN system standards and limits.

(4) Correlation of information to be provided by the Monitor System for facility and DSN system reports, both real time and non-real time.

(5) Adaptability to a wide range of DSN configurations, mission types, and mission loading.

5. Monitor Constraints

The following constraints will be observed by the Monitor System:

(1) The Monitor System will not preclude the data flow of other DSN systems, nor is it mandatory that the Monitor System be operational in order to deliver real-time data to Telemetry, Tracking, or Command System user.

(2) Each facility monitor system will be capable of operating independently from the SFOF Monitor.

(3) Definition of DSN configuration and capability requirements or changes shall be received by the Monitor System as changes to the monitor criteria data (MCD) sets, not as changes to the Monitor System.

6. System Operation

a. System description. The DSN Monitor System functionally resides in four processors, one in each DSN facility (DSIF, GCF, SFOF) and one in the DSN. Figure 1 is a functional data flow chart of the DSN Monitor System.

Each facility monitor processor will accept reports of configuration, load, performance, and status from the facility instrumentation and will accept reports on data accountability and quality from the DSN Tracking, Telemetry, and Command System processors. In addition, each facility processor will accept all standards and limits from the DSN monitor processor and distribute them to the appropriate error detectors. A facility analysis program will compare actual against standard configuration, load, status, accountability, and quality and will alarm nonstandard performance to the facility control and to the DSN Monitor System. Ground Communications Facility performance parameters measured at a DSS will be reported to the DSIF monitor or to the GCF monitor or both. The DSN monitor processor will provide applicable monitor data to the DSN facility chiefs and DSN system operations group. Nonstandard performance will be automatically alarmed by the DSN monitor processor. Alarms will be routed

to the system and facility involved and to the DSN Operations Control System. Reports on performance data will be made to facilities and systems as required.

Raw standards and limits will be gathered from each facility and from each DSN systems operations group and processed against a single instrumentation catalog for distribution to facilities for their system error detectors as facility-specific data sets.

A DSN monitor SDR (also called a DSN status SDR) will be made by the Monitor System from recorded DSN monitor data, which will be subsequently processed into a DSN extract data record in accordance with the processing criteria of the DSN Monitor Operations Control System.

b. Instrumentation and reports catalog. The instrumentation and reports catalog will consist of a file of DSN Operations Control and Monitor instrumentation in its current configuration. As a minimum, it will include details of standards and limits, data display formats, report requirements, and associated design data as required.

c. DSN Monitor System standards and limits. The DSN Monitor Operations Group will gather the required inputs, validate for accuracy, completeness, and compatibility between facility and DSN system subsets, and maintain the DSN standards and limits file. The types of inputs used shall be:

(1) DSN configurations from the scheduling activity.

(2) Detectable control actions expected (sequence of events) from Operations Control.

(3) DSN status display content requirements.

(4) The DSN instrumentation catalog (a description of each instrumented DSN element).

(5) Data content requirements for each summary report.

d. Initialization. The DSN Monitor Operations Group will coordinate, verify, check for consistency, and control the distribution of the standards and limits to each facility and each DSN system.

e. System performance monitoring. Each facility monitor system and the DSN Monitor System will automatically output specific alarm messages to the DSN Operations Control System based on nonconformance with standards or required performance.

f. Data quality and accountability reports. Data quality and accountability reports to other DSN systems are based on discrepancy reports from GCF monitoring and the DSN Telemetry, Tracking, and Command System status report. The reports shall identify (if possible) the records that were missed or that contain bad data. Information on known performance anomalies shall be correlated with the status report. This report allows the DSN system operations groups to make an immediate post-pass recall to fill in missing data in the master data record (MDR).

g. DSN Monitor System operational testing. The DSN Monitor System, under control of the DSN Monitor Operations Group in the SFOF, will be able to complete a Monitor System readiness and verification test in less than 15 min after startup (exclusive of communications setup and on-site calibration time). This test will be based on a standard data set for each facility monitor and on standard known output generated from test formats initialized in the DSN Monitor System.

h. Analysis. All DSN monitor data required for post-pass analysis of DSN performance will be received by the Monitor System in real time. Shipment of individual facility monitor system tapes will not be required to make any DSN monitor report. The DSN Monitor Operations Group in the SFOF shall provide access for each of the DSN systems operations groups to all monitor data concerning the performance of that group's system or any of the quality and accountability data that have been reported to the Monitor System by the data system error detectors.

i. Monitor System records. Monitor System records are shown schematically in Fig. 2. The original data records (ODRs) recorded at each DSS are compatible with both DSS and SFOF computers. They contain time-tagged data on station configuration, instrumentation performance, and spacecraft-dependent data such as ground receiver automatic gain control (AGC), static phase error (SPE), and signal-to-noise ratio (SNR). The records contain information transmitted to the SFOF and facility monitor data of local interest only. These records are available by mail or by replaying from the station.

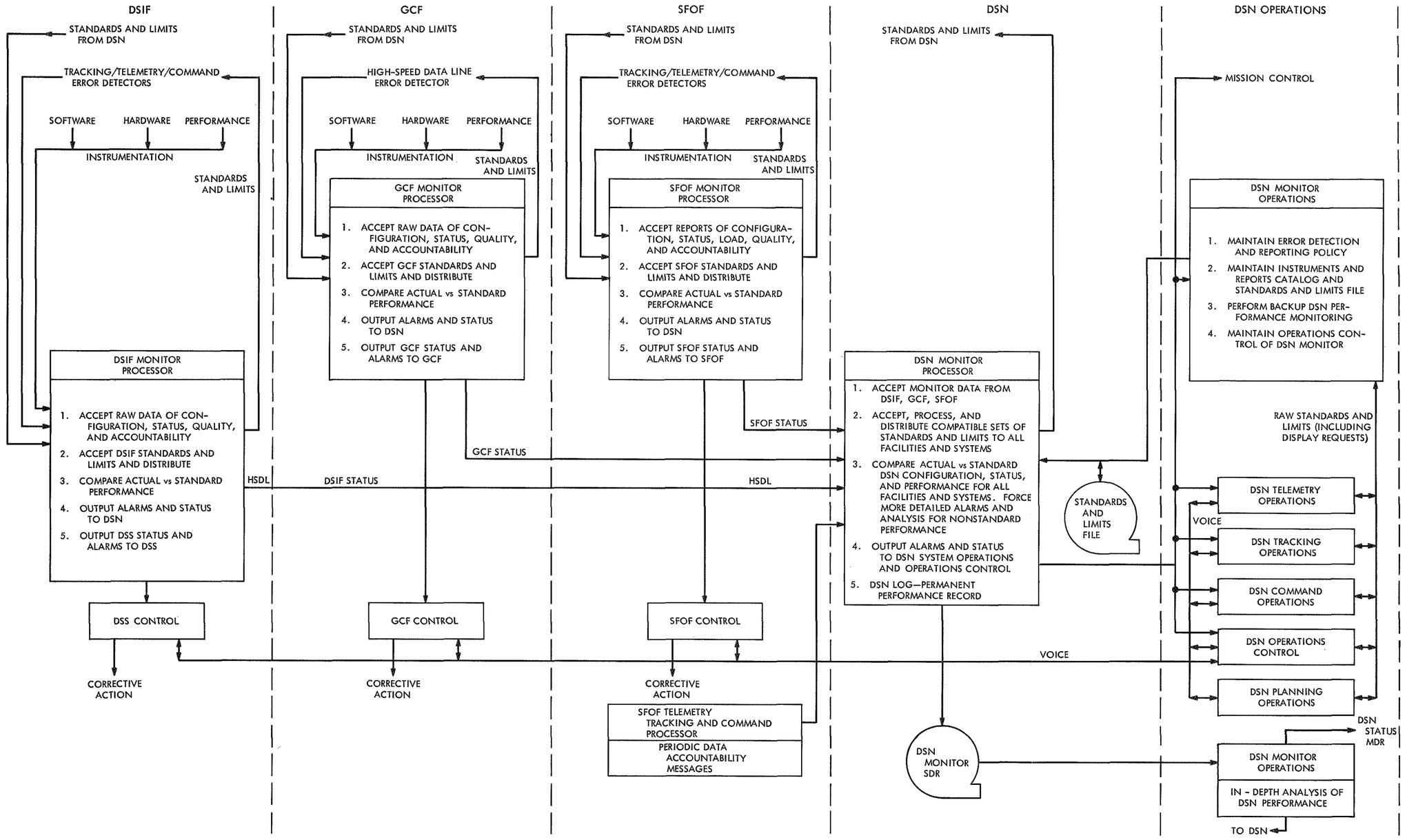
DSIF
STANDARDS AND LIMITS FROM DSN
TRACKING/TELEMETRY/COMMAND ERROR DETECTORS
SOFTWARE
HARDWARE
PERFORMANCE
INSTRUMENTATION
STANDARDS AND LIMITS
DSIF MONITOR PROCESSOR
1. ACCEPT RAW DATA OF CONFIGURATION, STATUS, QUALITY, AND ACCOUNTABILITY
2. ACCEPT DSIF STANDARDS AND LIMITS AND DISTRIBUTE
3. COMPARE ACTUAL vs STANDARD PERFORMANCE
4. OUTPUT ALARMS AND STATUS TO DSN
5. OUTPUT DSS STATUS AND ALARMS TO DSS
DSS CONTROL
CORRECTIVE ACTION
GCF
STANDARDS AND LIMITS FROM DSN
HIGH-SPEED DATA LINE ERROR DETECTOR
SOFTWARE
HARDWARE
PERFORMANCE
INSTRUMENTATION
STANDARDS AND LIMITS
GCF MONITOR PROCESSOR
1. ACCEPT RAW DATA OF CONFIGURATION, STATUS, QUALITY, AND ACCOUNTABILITY
2. ACCEPT GCF STANDARDS AND LIMITS AND DISTRIBUTE
3. COMPARE ACTUAL vs STANDARD PERFORMANCE
4. OUTPUT ALARMS AND STATUS TO DSN
5. OUTPUT GCF STATUS AND ALARMS TO GCF
GCF CONTROL
CORRECTIVE ACTION
SFOF
STANDARDS AND LIMITS FROM DSN
TRACKING/TELEMETRY/COMMAND ERROR DETECTORS
SOFTWARE
HARDWARE
PERFORMANCE
INSTRUMENTATION
STANDARDS AND LIMITS
SFOF MONITOR PROCESSOR
1. ACCEPT REPORTS OF CONFIGURATION, STATUS, LOAD, QUALITY, AND ACCOUNTABILITY
2. ACCEPT SFOF STANDARDS AND LIMITS AND DISTRIBUTE
3. COMPARE ACTUAL vs STANDARD PERFORMANCE
4. OUTPUT ALARMS AND STATUS TO DSN
5. OUTPUT SFOF STATUS AND ALARMS TO SFOF
SFOF CONTROL
CORRECTIVE ACTION
SFOF TELEMETRY TRACKING AND COMMAND PROCESSOR
PERIODIC DATA ACCOUNTABILITY MESSAGES
DSN
STANDARDS AND LIMITS FROM DSN
DSN MONITOR PROCESSOR
1. ACCEPT MONITOR DATA FROM DSIF, GCF, SFOF
2. ACCEPT, PROCESS, AND DISTRIBUTE COMPATIBLE SETS OF STANDARDS AND LIMITS TO ALL FACILITIES AND SYSTEMS
3. COMPARE ACTUAL vs STANDARD DSN CONFIGURATION, STATUS, AND PERFORMANCE FOR ALL FACILITIES AND SYSTEMS. FORCE MORE DETAILED ALARMS AND ANALYSIS FOR NONSTANDARD PERFORMANCE
4. OUTPUT ALARMS AND STATUS TO DSN SYSTEM OPERATIONS AND OPERATIONS CONTROL
5. DSN LOG—PERMANENT PERFORMANCE RECORD
STANDARDS AND LIMITS FILE
DSN MONITOR SDR
SFOF STATUS
GCF STATUS
HSDL
DSIF STATUS
HSDL
VOICE
DSN OPERATIONS
MISSION CONTROL
DSN MONITOR OPERATIONS
1. MAINTAIN ERROR DETECTION AND REPORTING POLICY
2. MAINTAIN INSTRUMENTS AND REPORTS CATALOG AND STANDARDS AND LIMITS FILE
3. PERFORM BACKUP DSN PERFORMANCE MONITORING
4. MAINTAIN OPERATIONS CONTROL OF DSN MONITOR
RAW STANDARDS AND LIMITS (INCLUDING DISPLAY REQUESTS)
DSN TELEMETRY OPERATIONS
VOICE
DSN TRACKING OPERATIONS
DSN COMMAND OPERATIONS
DSN OPERATIONS CONTROL
DSN PLANNING OPERATIONS
VOICE
DSN STATUS MDR
DSN MONITOR OPERATIONS
IN - DEPTH ANALYSIS OF DSN PERFORMANCE
TO DSN

Fig. 1. DSN Monitor System functional flow diagram

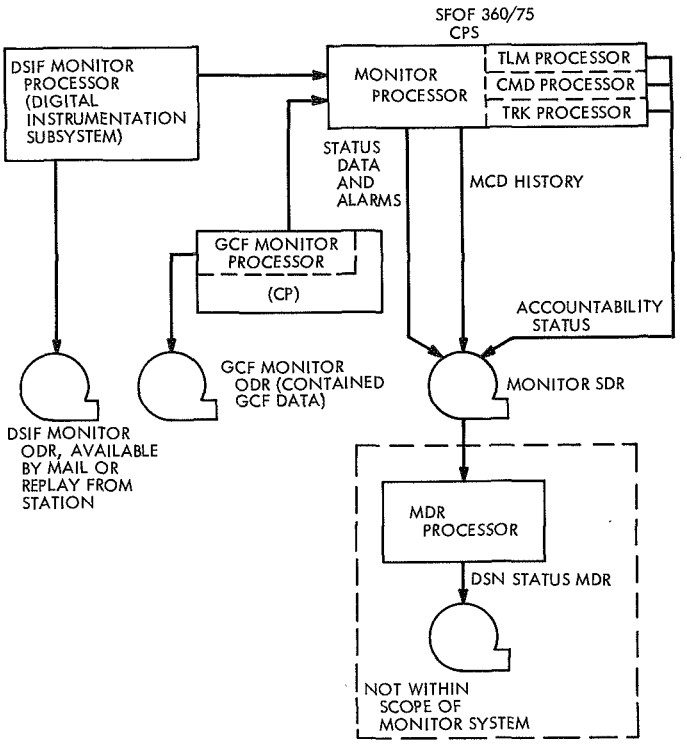

Fig. 2. Monitor data flow

The GCF monitor ODR is processed in the communications processor (CP) in the SFOF. The GCF status data are combined with data from other DSN systems. They contain data on HSDL performance and CP performance and are available by CP recall.

The SFOF monitor ODR is contained on the DSN monitor SDR. The DSN monitor SDR contains the DSIF monitor data transmitted from each DSS to the Central Processing System (CPS) in the SFOF, the GCF monitor data transmitted from the CP to the CPS, and the SFOF monitor data that originate in the SFOF and are processed by the CPS. It also contains a history of monitor criteria data (MCD) set usage and a history of all DSN monitor alarms. The DSN status MDR is obtained by processing of the DSN monitor SDR.

7. Performance Parameters

a. Monitor system support capabilities. The DSN Monitor System will provide capability for processing and displaying up to five DSIF monitor data streams and GCF and SFOF monitor data. Each facility will provide monitor processing for facility monitor and control for Tracking, Telemetry, and Command System status reports. All such monitor processing will be provided simultaneously with the tracking, telemetry, and command data handling.

The DSN Monitor System capability will be sufficient to accept, sort, store, process, and display all monitor data output from the DSS, GCF, and SFOF for all missions supported.

The DSN Monitor System is configured to:

(1) Be initialized in less than 15 min, excluding station calibration and time to activate communication circuits.

(2) Produce a validated System Data Record (SDR) within 12 h after each pass.

(3) Have a response time of less than two days to handle new requirements imposed by new operational instrumentation or display requests.

(4) Have a reliability factor based on a failure recovery time of 10 min for restart.

b. Monitor criteria data. The MCD set is a list of parameters by which the stations' configurations can be determined. Each station is configured to handle each mission in a special way, and each station has a different complement of equipment. To insure that each station is configured in the right way as specified in the sequence of events, each station's parameters are masked against a known set of parameters.

In the event that the station's configuration is not as it should be, an alarm is output to the user and he then corrects the configuration.

The MCD input processor, located in the IBM 360/75 computer at JPL SFOF, will perform the essential task of validating MCD file information, provide for correction and update to the existing MCD file, and structure the MCD master file, used by the MCD activation and assembly program, so that the required data for MCD set construction may be accessed in an efficient manner. The input processor will operate in the batch mode under JPL operating system.

The MCD activation program is the basic interface between the MCD processors and the external world, with the prime responsibility of message processing between the monitor request processor and the MCD

assembly program. The activation program validates input messages and processes operator requests according to their type and origin (i.e., card, 2260, etc.). It provides a series of information displays on MCD subsystem status for operations control. For valid requests, the activation program will request the MCD assembly program to construct a set of MCD data. Depending on the dialogue via the monitor request program, the activation program may cause MCD set creation, modification, deletion, transmission, or simply display status information.

Additionally, inputs will be received by the activation program via the tracking and telemetry processor. These data will consist of tracking standards and limits modification. The activation program will present this information to the MCD processor program for use in processing the DSN raw data file.

The purpose of the MCD sets is to provide facility configuration display by which subsystem analysis and performance can be determined.

In order to obtain a high degree of flexibility, the MCD program is contained in three main files (see Figure 3). These are:

File 1 *Subsystem configuration (hardware)*: A description of the various equipment at the DSIF and their associated switch positions.

File 2 *Configuration mode*: A description of the modes of operations of the various hardware and associated switch positions.

File 3 *Standard MCD set*: A series of numerical matrix listings comprised of hardware configurations listed in file 1 and configuration modes listed in file 2.

The MCD assembly program is responsible for receiving requests for standard MCD set activation, modification of a specified parameter within a standard set, requesting generation of a new MCD set and indexing file 3 with this request, receiving completed request from file 2, and transmission of completed sets to the DSIF for implementation.

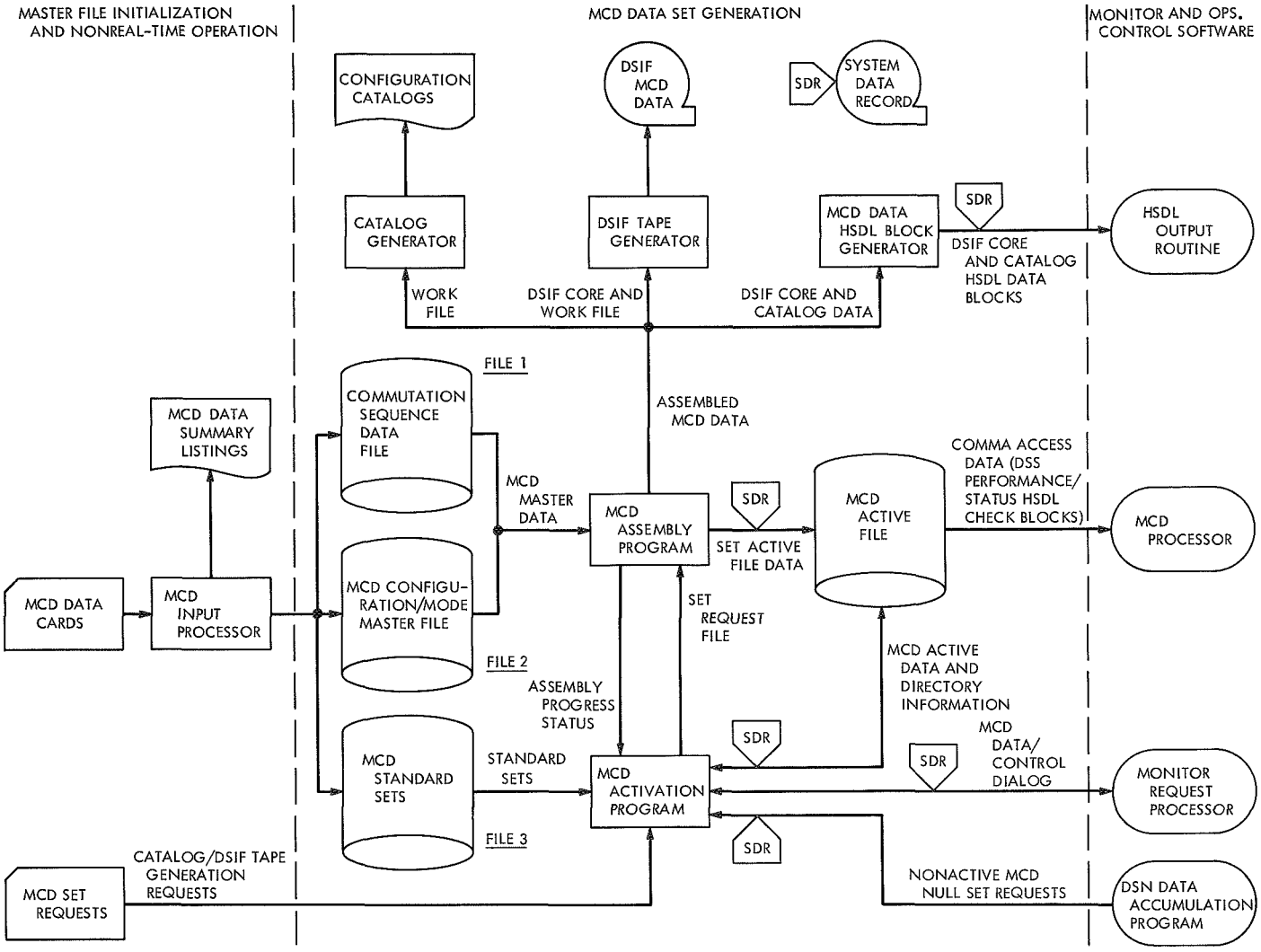

Fig. 3. Monitor and operations control MCD set generator